Repairing Damaged Wildlands

A Process-Oriented, Landscape-Scale Approach

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Introduction

Wildlands are forests, grasslands, savannas, deserts, wetlands, shrublands, marshlands or other extensively managed areas for which a self-sustaining, and usually perennial, vegetation is the management objective. They often have a relatively low productivity and/or produce goods and services with relatively low market values. However, wildlands, which comprise most of the earth's land area, are very important because they provide food, fiber, recreational amenities, contribute to biological diversity, and control the quality and amount of water for many urban and agricultural uses.

Although initial degradation of wildland ecosystems alters species composition, those areas initially retain control over essential resources (i.e., soil, water, nutrients, and organic materials). Degradation becomes more severe as the area loses control over essential resources (Chapin *et al.*, 1997). Seriously damaged wildlands not only lost control over resources, they lost the capacity for self-repair and are unable prevent additional degradation. Thus, they are less resilient to additional stress or damage and provide fewer environmental services (Myers, 1996). As these degrading processes continue, the area crosses a threshold, beyond which it can no longer recover. This is desertification. Once begun, desertification is a dynamic, self-perpetuating process (Tivy, 1990; Thurow, 1991).

Wildland degradation has two components (socioeconomic and biophysical) that complicate its assessment. The expectations of societies or individual managers for the production of goods and services influence perceptions of wildland degradation. Species composition shifts reduce socioeconomic values without negatively affecting its ability to retain essential resources. Biophysical degradation, the primary focus of this book, occurs when wildland ecosystems lose the ability to retain essential resources. Since biophysical degradation usually has an adverse effect on socioeconomic values, it is included in most assessments of degradation. Some assessments consider the degradation of socioeconomic values, while others do not.

Describing the effects of degradation at regional to global scales is complicated by imprecise information, too little information, and the use of numerous, poorly defined categories of degradation. Thus, global estimates of degradation are rough estimates of variously defined categories. Despite variable definitions, they clearly indicate that serious problems exist on a large scale. For example, almost 17% of the world's vegetated area (20 million km^2) became degraded between 1945 and 1990 (WRI, 1992). Nearly 61% of the world's productive drylands were moderately desertified by 1984 and at least 80% of the rangelands in developing countries were desertified (Mabutt, 1984). Over 12 million km^2 are damaged beyond the repair capacity of individual farmers; 3 million km^2 need extensive engineering work; and 10 000 km^2 are beyond any repair (Mabutt, 1984; Tivy, 1990; Harrison, 1992). Each year an additional 60 000 km^2 are irretrievably lost to degradation (UNEP, 1984). Although damage to wildland ecosystems is defined in many ways and is difficult to quantify with precision, it is clearly a major global problem.

Even the most optimistic estimates of worldwide degradation or desertification indicate the need for ecological repair that far exceeds our capacity to repair damaged wildlands with contemporary approaches. Fortunately, it is possible to initiate natural, plant-driven (autogenic) recovery processes that do not require continuing management subsidies, even on the most degraded sites. Our ability to repair damaged ecosystems is a critical element in the management of the world's environment (Dobson, Bradshaw & Baker, 1997). Wildland economies demand minimal management inputs to initiate autogenic repair processes. Repairing the most severely damaged wildlands may require removal of the physical limitations of the degraded landscape with soil surface modifications that help capture and retain water, soil, nutrients, and seed. While these surface modifications are temporary, they can facilitate establishment of vegetation with the potential to improve conditions. Functionally, repair is completed when predisturbance energy capture rates are restored, nutrient export is minimized, and control of water-use efficiency is realized (Breedlow, Voris & Rogers, 1988). From a practical perspective, certain goods or services are required from these repaired ecosystems.

Repairing damaged wildlands requires realistic objectives that consider the extent of damage, ecological potential, land-use goals, and socioeconomic constraints. Since wildland ecosystems are dynamic and constantly changing, rather than static and predictable, it is unrealistic to set predefined species groups as goals. Instead, redirecting essential ecosystem processes toward preferred trajectories should repair damaged wildlands.

Since the number of potential combinations of objectives, approaches, limitations, and wildland types is almost infinite, step-by-step recommendations are seldom useful. The goal of this book is to describe a framework for repairing damaged wildlands that (1) is process-oriented; (2) seeks to initiate autogenic repair; and (3) considers landscape interactions. The suggested approach begins by assessing the functionality of important primary processes (hydrology, energy capture, and nutrient cycling) and by encouraging positive feedback mechanisms that initiate autogenic repair processes. Positive feedbacks support and reinforce change. That change may either be desirable (improving functionality or conditions) or undesirable (declining functionality or conditions). In contrast, negative feedbacks maintain existing conditions by resisting change. Again, we consider these feedback mechanisms desirable when they resist degradation and maintain functionality. Thus, negative feedbacks that maintain degraded functions and resist improvement are undesirable. Recognizing and appropriately directing these feedback mechanisms will significantly improve our ability to repair damaged wildlands. This is an important goal of this book.

Most contemporary wildland repair programs differ from the approach described in this book in three fundamental ways. First, they emphasize the return of structure (e.g., nutrients and selected plant species) rather than the repair of processes (e.g., hydrology, nutrient cycling, and energy capture). Second, they focus on specific sites without considering the landscape context. Third, they view the 'repair' program as the completion, rather than a beginning of natural repair processes. A focus on returning structural components to functionally damaged ecosystems does not necessarily lead to the development of self-repairing wildland ecosystems.

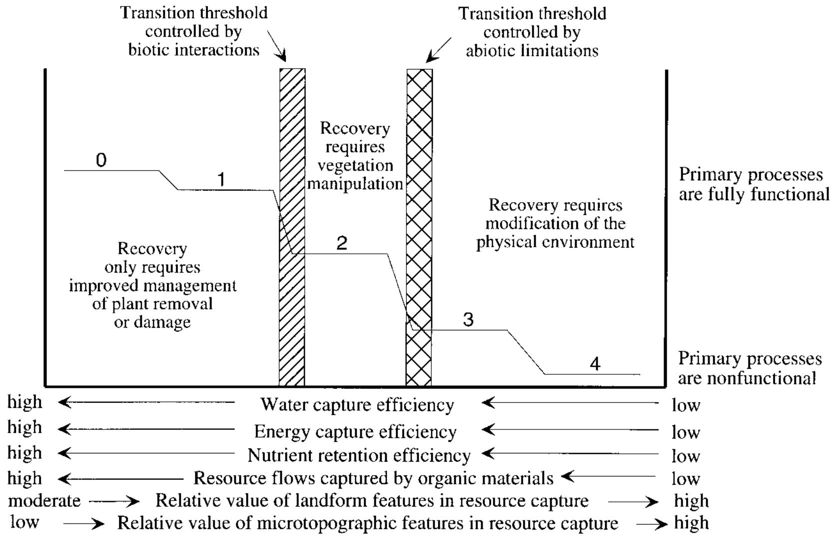

Figure 1.1. Stepwise degradation of hypothetical wildland vegetation illustrating the two common transition thresholds that separate the three vegetative groups emphasized here. Their functional integrity and transition limitations, rather than species composition, define these groups. Wildlands controlled by biotic interactions require some form of vegetation manipulation (some species must be planted while others must be removed) before recovery can occur. Transition thresholds controlled by abiotic limitations require physical manipulations that increase infiltration, reduce erosion, capture organic materials, and/or ameliorate microenvironmental extremes. Vegetative states 0 to 4 follow Milton *et al.* (1994) and are described in Table 1.1.

Degradation

Healthy ecosystems have built-in repair mechanisms, but damage can exceed their capacity for self-repair (Figure 1.1). After crossing that self-repair threshold, natural (unassisted) repair mechanisms cannot repair all the damage. Removing this threshold-related impediment to natural recovery requires active intervention. Our goal is the minimum intervention that removes impediments to autogenic recovery. This does not produce immediate repair; it simply initiates self-repair processes that lead toward properly functioning ecosystems. For our purposes, properly functioning wildlands conserve resources, retain the capacity for self-repair, and provide goods and services that contribute to ecological and socioeconomic sustainability.

Activities that damage and remove vegetation or soil at unsustainable rates damage ecosystem functions. Biomass removal and physical disturbances degrade wildlands. Biomass removal from chronic disturbances (e.g., abusive grazing, fodder removal, or fuelwood collection) damages and kills plants. Acute disturbances remove excessive biomass in single events (e.g., rapid deforestation). Vehicles pack the soil and damage vegetation. Cultivation and mining activities damage and/or remove the soil. Degradation (1) reduces the number of desired plant and animal species; (2) reduces plant biomass; (3) decreases primary production; (4) reduces energy flow to grazing and decomposer components of the food chain; (5) depletes macronutrient pools; and (6) reduces soil stability. Damaged hydrologic, nutrient cycling, energy capture, and vegetation processes contribute to positive feedback systems that increase degradation.

Milton *et al.* (1994) described these changes with a conceptual model of grazing-induced degradation in arid and semiarid ecosystems. They described the symptoms of degradation and suggested focal points for management actions. Thus, it provides a framework for initial damage assessment and preliminary planning of repair strategies (Table 1.1). It is particularly important to recognize the early symptoms of degradation, since management expenses increase with each additional step in the degradation process.

Climatic cycles and stochastic events (Figure 1.2) drive changes on relatively undamaged sites (step 0). Drought, disease, fire, hail, hurricanes, and mudslides cause mass mortality or episodic recruitment that alter species composition and production. Excessive biomass removal over long periods of time usually alters plant populations (Milton *et al.*, 1994), increasing certain species, or life forms, at the expense of others (step 1). The vigor of these frequently defoliated plants is reduced and they produce fewer viable seed. The most effective management option for both these relatively intact areas is adaptive management of the consumers of the ecosystem's primary production. This might involve managing livestock grazing, managing excessive wildlife populations, wood removal, timber harvest, fodder cutting, or other forms of vegetation removal.

With continued overharvest, biological diversity and productivity decrease (step 2) and many of their symbionts and specialized predators are lost (Milton *et al.*, 1994). Reducing plant productivity initiates a series of changes that eventually decrease soil fertility, infiltration rate,

Table 1.1. *Stepwise degradation of wildland landscapes*

Step number	Description	Symptoms	Management options	Appropriate focus for initial repair activities
0	Biomass and composition of vegetation varies with climatic cycles and stochastic events	Perennial vegetation changes are associated with varying climatic conditions (precipitation or temperature) rather than with consumption of primary production. Primary processes are undamaged.	Adaptive management of herbivory, wood harvesting, hay or fodder removal.	Secondary producers (consumers of the ecosystem's primary production) (See Chapter 4)
1	Selective consumption reduces recruitment of most desired plants, allowing populations of less preferred species to expand	Age distribution of plant populations changes to older plants. Primary processes are undamaged.	Stricter control of herbivory, wood harvesting, haying, fodder removal, or other form of selective consumption of plants.	Secondary producers (consumers of the ecosystem's production) (See Chapter 4)
2	Plant species that fail to recruit are lost, as are their specialized predators and symbionts	Plant and animal losses, reduced secondary productivity. Primary processes are damaged, but functioning.	Manage vegetation (e.g., add, remove, or modify) with planting, fire, herbicides, biological, cultural or other methods.	Primary producers (See Chapters 4–7)

3	Biomass and productivity of vegetation fluctuates as ephemerals benefit from loss of perennial cover	Perennial biomass reduced (short-lived plants and instability increase), resident birds decrease, and nomads increase. Primary processes are only partially functional.	Manipulate soil cover (e.g., mulching, erosion barriers, roughen soil surface). Use carefully selected woody vegetation to modify micro-environmental conditions.	Physical environment (See Chapters 2–7)
4	Denudation and desertification involve changes in soil function and detritivore activity	Bare ground, erosion, and aridification. Primary processes are nonfunctional.	Manipulate soil cover (e.g., mulching, erosion barriers, roughen soil surface). Use woody vegetation to modify micro-environmental conditions.	Physical environment (See Chapters 2–7)

Notes:
Symptoms describe the state of plant and animal assemblages, management options refer to actions that a manager could take to repair the site, and the last column refers to the system (level of the food chain) at which management intervention should begin.
Source: Adapted from Milton *et al.*, (1994). Used with permission of the author and the American Institute of Biological Sciences.

Figure 1.2. Relatively intact wildlands – like this in Yellowstone National Park – retain control over the capture and retention of limiting resources (water, soil, nutrients, energy, and organic materials). Although step 0 is considered unchanged and step 1 has undergone changes in species composition and productivity (Milton *et al.*, 1994), they are functionally similar. Since these areas are fully functional they retain the capacity for self-repair following disturbance (such as fire in this example).

and water-holding capacity. Wildlands in this condition (Figure 1.3) seldom recover naturally without management intervention that adds and/or removes species. Reversing degradation at this stage has severe economic restrictions, since it requires both income reductions (fewer livestock) and expenditures for vegetation manipulation (seeding, burning, herbicide treatments, or selective plant removal).

Continued reductions in plant productivity decrease litter and vegetative soil cover, which in turn increases erosion and extremes of soil temperatures (Barrow, 1991). Under these conditions, weedy and ephemeral species flourish and outcompete seedlings of perennial plants. Repairing damaged wildlands at this stage (steps 3 and 4) is unlikely to succeed without addressing the physical limitations of the degraded landscape. These physical limitations are also important in the most advanced stage of degradation (Figure 1.4). These sites have advanced erosion, barren landscapes, are extremely difficult to repair,

Figure 1.3. This Texas site was formerly grassland, but is now dominated by honey mesquite (*Prosopis glandulosa*) and pricklypear (*Opuntia* spp.) and is less productive or produces less of commercial value. Since primary processes are damaged, but still functional, wildlands might be managed to remain at this stage in some situations. This site has passed through a transition threshold that is irreversible without significant management intervention that removes and/or adds plant species.

and recovery may be very slow. Many of these most degraded sites are simply abandoned because repair costs exceed anticipated economic benefits (Barrow, 1991). Fortunately, it is possible to initiate autogenic recovery processes that do not require continuing management subsidies, even on the most degraded sites (Whisenant, Thurow & Maranz, 1995).

Setting realistic objectives

Defining project objectives is the most important single step in the planning process (Pastorok *et al.*, 1997). Specific objectives and knowledge of the economic and biologic restrictions increase the probability of designing and implementing successful repair projects. Repair objectives should specify (1) goals for abiotic functions, performance of

Figure 1.4. This severely degraded landscape in Shaanxi Province, People's Republic of China, is relatively nonfunctional, since it is unable to capture or retain soil, nutrients, water, or organic materials flowing through the landscape. The silted-in reservoir illustrates the magnitude of erosion problems on this landscape. Since little water moves into the soil and there is little vegetation to moderate environmental extremes, it is difficult for plants to become established. Recovery of this site will require physical modifications that reduce abiotic limitations imposed by the lack of vegetation. Despite steep slopes, this area has the ecological potential to develop into forests that stabilize the landscape and retain a high percentage of resource flows. However, socioeconomic pressures (high human population) greatly restrict that option on this landscape.

primary processes, species, communities, and landscape arrangements; (2) landuse, habitat, and/or esthetic goals; (3) spatial scales and time period goals; and (4) performance goals for all important objectives.

Landuse goals, social interactions, economics, management preferences, and biotic and abiotic limitations determine wildland repair objectives. Numerous questions relating to our objectives are important to consider. What are the economic constraints of the program? Must short-term production economics pay for the program or are long-term environmental considerations of overriding importance? Programs designed to restore native vegetation have unique economic environments. Biodiversity programs often emphasize the management and maintenance of ecosystem function and species survival. The unique goals of each program will set the direction of the planning effort.

Damaged wildlands are repaired in many ways and in pursuit of various objectives, but sustainability is the primary objective. The relative importance of social, cultural, economic, or biologic concerns determines our view of sustainability. Sustainable development is 'the maintenance of essential ecological processes and life support systems, the preservation of genetic diversity, and the sustainable use of species and ecosystems' (IUCN, 1983). It is also defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (UNEP, 1987). Truly sustainable development requires micro- and macroeconomic evaluations that realistically appraise the environmental consequences of alternative management strategies. Unfortunately, contemporary economic accounting systems seldom consider the adverse environmental impacts of alternative management strategies (Daley, 1991).

What do we call what we want to accomplish?

The literature is complicated by numerous inconsistent definitions of terms that describe the objectives of wildland repair (Table 1.2). These definitions are important because (1) we need clear, well-defined goals; and (2) we should be able to communicate those goals without ambiguity. Unfortunately, we must describe our goals for each situation, since most terms have multiple common uses. Because the literature contains numerous terms, I will briefly review a few of them.

Many restoration efforts seek to return damaged wildlands to some predefined indigenous ecosystem, resembling the original in all respects (Table 1.2). This strict definition of restoration focuses on structure (species), rather than function. This structural focus contributes to ambiguous goals and success criteria (Cairns, 1989; Cairns, 1991). Since we seldom understand the composition, structure, function, or dynamics of historic ecosystems it is difficult to measure success against that goal.

The Society for Ecological Restoration (SER, 1994) went through a relatively rapid change in its concept of ecological restoration (Table 1.2). In three years, their official view of restoration

Table 1.2. *Selected terminology describing objectives for improving ecological condition of damaged wildlands*

Terminology	Definition	Source
Ecological repair	Generic term for improving ecological conditions on damaged wildlands by emphasizing the repair of primary ecosystem processes. Seeks to meet management objectives by developing ecosystems' capacity for self-repair and maintenance.	
Restoration	Return to exact predisturbance conditions.	(NRC, 1974)
	The intentional alteration of a site to establish a defined indigenous, historic ecosystem that emulates the structure, functioning, diversity, and dynamics of previous ecosystem (Society for Ecological Restoration in 1990).	(SER, 1994)
	The process of reestablishing to the extent possible the structure, function, and integrity of indigenous ecosystems and the sustaining habitats they provide (Society for Ecological Restoration in 1993).	(SER, 1994)
	The process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystem (Society for Ecological Restoration in 1994).	(SER, 1994)
	Return of damaged or degraded ecosystem to its presumed or relatively original indigenous state.	(Brown & Lugo, 1994)
	sensu stricto: same as Society for Ecological Restoration in 1990.	(Aronson *et al.*, 1993a)
	sensu lato: 'Endeavors that seek to halt degradation and to redirect a disturbed ecosystem in a trajectory resembling that presumed to have prevailed prior to the onset of disturbance.'	(Aronson *et al.*, 1993a)
Reclamation	Reclaimed site will be similar in ecological functioning and contain similar but not necessarily the same organisms.	(NRC, 1974)
	'Process by which derelict or very degraded lands are returned to productivity and by which some measure of biotic function and productivity is restored.'	(Brown & Lugo, 1994)
Rehabilitation	Making the land useful again but with different land use and different species.	(NRC, 1974)
	Any act of improvement from a degraded state.	(Wali, 1992; Bradshaw, 1997) (Aronson *et al.*, 1993a)

	Repair damaged ecosystem functions with the primary goal of raising ecosystem productivity for the benefit of local people. Adopts the indigenous ecosystem's structure and function as the principal model and is directed at recreating self-sustaining system.	(Aronson *et al.*, 1993a)
	Return of any damaged or degraded ecosystem to a fully functional ecosystem, without regard to its original or desired final state.	(Brown & Lugo, 1994)
Ecological engineering	'design of human society with its natural environment for the benefit of both.'	(Mitsch & Jørgensen, 1989)
	'environmental manipulation by man using small amounts of supplemental energy to control systems in which the main energy drives are still coming from natural sources.'	(Odum, 1962)
Reallocation	Landscape is 'assigned new use that does not necessarily bear an intrinsic relationship with the predisturbance ecosystem's structure or functioning. Reallocation assumes a permanent managerial role for people and normally requires ongoing subsidies in the form of energy, water, and fertilizers."	(Aronson *et al.*, 1993a)
Reconstruction	Generic term applicable to restoration, rehabilitation or reclamation.	(Allen, 1988a)
Landscape restoration	'The reintroduction and reestablishment of community-like groupings of native species to sites that can reasonably be expected to sustain them, with the resultant vegetation demonstrating aesthetic and dynamic characteristics of the natural communities on which they are based."	(Morrison, 1987)
Landscape rehabilitation	'full or partial placement of structural or functional characteristics that have been extinguished or diminished and the substitution of alternative qualities or characteristics than the ones originally present with the proviso they have more social, economic, or ecological value than existed in the disturbed or displaced state.'	(Cairns, 1988)
Assisted natural restoration	Repair that uses minimal management inputs to stimulate or direct succession.	variously described
Biocultural restoration	Restoration (conservation biology) that explicitly incorporates needs and desires of local inhabitants. 'Explicit and public agreement on management goals is imperative.'	(Janzen, 1988b)

evolved from restoring predefined, indigenous ecosystems (in 1990) to reestablishing the structure, function and integrity of indigenous ecosystems (in 1993) to repairing damage, caused by humans, to the diversity and dynamics of indigenous ecosystems (in 1994). This evolution of terminology reflected contemporary ecological views on succession.

Current ecological theory does not view succession as steady change toward predefined communities in equilibrium with their environment. Rather, it recognizes disturbance-induced discontinuities and irreversible transitions, nonequilibrium communities, and stochastic impacts in succession (Wyant, Maganck & Ham, 1995). In essence, striving to achieve a predefined equilibrium state may be neither possible nor desirable as a management goal (Wyant *et al.*, 1995). Restoration of some predefined ecosystem is unrealistic and/or impossibly expensive (Bradshaw, 1997).

Restoration ecology is a research-oriented discipline that enhances our understanding of ecosystem functioning and provides conceptual direction to manipulative efforts (Table 1.2). Restoration ecology provides a theoretical framework for ecological restoration and makes a valuable contribution by defining ecological principles, testing ecological theories, and facilitating communication between theorists and practitioners.

Rehabilitation (Table 1.2) is usually described as seeking to reduce site degradation and enhance productivity of self-sustaining ecosystems for the benefit of humans (Aronson *et al.*, 1993a). Self-sustaining implies the resilience to recover from any anticipated perturbations, whether human-caused or natural (Aronson *et al.*, 1993a). Rehabilitation resembles restoration in that it adopts the indigenous ecosystem's structure and function as much as possible, but without implying perfection (Bradshaw, 1997). It conveys the multiple objectives of halting degrading processes while increasing economic, ecological and esthetic benefits.

Reallocation (Table 1.2) is the conversion to a completely different landuse (Aronson *et al.*, 1993a). This conversion is recommended where the system is seriously degraded and where management objectives or human population pressures necessitate a radically different landuse such as cultivation, improved pasture (irrigated and/or fertilized), agroforestry or other non-wildland uses. Reallocation may require continuing subsidies of fertilizers, herbicides, energy, and water. Reallocation is often essential, but is no longer a wildland system and is not addressed in this book except as it interacts with wildland components within the landscape. These interactions among cultivated fields and wildland components are more fully addressed elsewhere (Aronson, Ovalle & Avendano, 1993c; Hobbs & Saunders, 1993).

Rather than argue over the precise terminology, it seems most useful to emphasize that repair activities occur along a continuum, and that different activities are simply variations of the same theme (Hobbs & Norton, 1996). Repair is a generic term to describe this continuum of objectives (Saunders, Hobbs & Erlich, 1993b; Brown & Lugo, 1994; Whisenant & Tongway, 1995). This book is intended to assist in assessing, planning, implementing, and monitoring these efforts in wildland ecosystems, regardless of specific objectives. Therefore, rather than dwelling on semantics, I will use the term 'repair' because it has broad meaning and suggests a process orientation. My use of the term (repair) implies the goal is the development of a self-repairing ecosystem that meets management objectives by repairing damaged primary processes, and initiating and directing autogenic processes. Placing the emphasis on processes acknowledges the dynamic (rather than static and predictable) nature of ecosystems and the futility of strict species abundance goals (Pickett, Parker & Fiedler, 1992; Pickett & Parker, 1994). This does not mean we repair processes and accept whatever occurs. On the contrary, we apply numerous technologies that direct changes toward management objectives.

Repairing damaged wildlands

Programs designed to improve the ecological status and/or productivity of damaged wildlands usually contain elements of two different approaches (agronomic and ecologic). Although their conceptual approaches differ, both make important contributions toward our understanding of the problems and to the actual repair efforts. The approach described here uses elements of both, but places an emphasis on repairing damaged primary processes and initiating autogenic repair processes on a landscape scale. This approach concentrates on real-world applications that address big problems with few resources by repairing function rather than simply returning structure.

Philosophical approaches

There are numerous philosophical and technological approaches toward improving degraded wildlands. Rather than attempting to describe each of the potential combinations, I will contrast two extremes to illustrate their philosophical differences (Table 1.3). The contrast between agronomic and ecological approaches is somewhat artificial since most repair efforts utilize elements of both, but it illustrates their potential strengths and weaknesses in order to begin discussing synergistic opportunities. The strengths and weaknesses of these approaches are situation specific and neither is universally superior. Successful wildland repair programs generally incorporate some unique combination of both approaches.

AGRONOMIC APPROACH

The philosophical and technological approaches of intensive agricultural endeavors are widely applied to wildland repair efforts, with mixed results. Traditional, agronomic-based approaches toward wildland repair are effective where the soil and climate are most conducive to production. They are also responsible for most of the successful efforts that have occurred in the past. This approach is particularly appropriate at increasing forage production, large-scale projects, and rapid site-stabilization. Modification of traditional farm equipment through several generations produced quality equipment for wildlands. Modified seed drills are now reliable on rocky, unplowed ground and tree transplanters work well on slopes. The quality and variety of equipment available for wildland repair continue to improve.

It is increasingly apparent that when site and environmental conditions are less desirable, the prevailing condition of most wildlands, the benefits of agronomic approaches are often short-lived or not feasible. This situation developed because we attempted to repair wildlands with nutrient subsidies and inorganic and organic amendments rather than by addressing the functioning of the system as a whole. Wildlands are managed as renewable resources with limited subsidies. Sustainable wildland repair strategies must improve the efficiency of resource capture and use within the landscape.

Common shortcomings of the agronomic approach include the possibility of problems due to inefficient nutrient use, poor nutrient retention, narrowed gene pools, low functional diversity, and reliance on elevated management inputs. These agronomic-based strategies are appropriate in some situations, but are impractical on landscapes with marginal productive potential or in developing countries where agricultural chemicals and equipment are unavailable. In relatively predictable conditions, with good edaphic and climatic conditions, this approach can stabilize soils and increase productivity. In less predictable environments, such as arid and semiarid regions, agronomic-based revegetation technologies are less successful because they are neither ecologically based nor economically feasible.

ECOLOGICAL APPROACH

The search for alternative repair strategies and interest in sustainable agriculture stimulated the application of ecological concepts during the repair process. Repair actions initiate a dynamic successional response, toward management goals. Ecologically based approaches direct vegetation change through the enlightened application of ecological principles (Bradshaw, 1983). This approach seeks to create communities and landscapes that persist and develop toward desired conditions. Ecological landscape repair strategies increase and sustain advantageous biological interactions, whereas agronomic approaches typically reduce those biological interactions. Ecological repair strategies do not preclude the use of traditional agronomic practices. The integration of agronomic and ecological practices is very effective.

Ecological strategies modify and enhance soil and microenvironmental conditions with natural processes. The objective is a reduced subsidy approach that uses vegetation suited to existing conditions or vegetation with the ability to improve soil and microenvironmental conditions. Traditional repair efforts often work against normal processes of vegetation change by attempting to maintain artificial communities. Ecologically based approaches often have lower initial investments, but require considerably more time to achieve management goals. Some ecologically oriented projects, particularly in developed countries, are very labor intensive (Cottam, 1987) or equipment intensive and costly (Bruns, 1988). Some programs are implemented with volunteer labor. Governments and private enterprise fund repair programs to mitigate damage caused by mining, construction, or other activities deemed essential to society.

Table 1.3. *Contrasting approaches to the repair of damaged wildlands*

Planning consideration	Agronomic approach	Ecologic approach
Economics	Emphasis on near-term economic return. Suited to conditions where higher probabilities of successful establishment and productive potential allow greater initial investments and continuing management inputs.	Emphasis on long-term ecologic stability and reduced management input. Suited to less favorable or less predictable environments, situations where economic expenditures must be limited, where time is not driving the decision-making process, or where a more stable, natural vegetation complex is the primary objective.
Site selection	Focus on sites with greatest productive potential and greatest probability of returning economic investment.	Focus on sites with greatest potential for meeting ecologic objectives. Those objectives may be soil stabilization, species diversity, structural diversity, functional diversity, or wildlife habitat and do not necessarily include economic performance.
Species selection	Select species that are compatible with management objectives and achieve maximum productivity under the existing soil, climatic, and management environment.	Species may meet objectives either directly or indirectly. Some species may be selected to modify soil or microenvironmental conditions, thus facilitating subsequent recruitment of additional species by natural or artificial means. Species may be used to inhibit the development of other species.
Seedbeds and microsites	Seedbeds are prepared for the site, environmental conditions, and species to be introduced. This may include cultivation, weed control, or chemical and structural changes to the soil.	Species are selected based on adaptation to existing seedbed conditions and may be selected for their site-modifying abilities rather than their ability to accomplish final objectives.

Spatial scale	Repair efforts planned at the stand or individual patch level. This may include single or multiple species mixtures, but seldom includes structural or functional considerations of interacting landscape elements.	Repair efforts planned and implemented at the landscape level to incorporate beneficial structural and functional relationships between interacting landscape elements.
Temporal scale	Benefits begin to be realized relatively rapidly. All species introductions usually occur at the same time.	Initial benefits may be realized less rapidly and full benefits may continue to accrue for years, even decades, as biotic interactions are manifested. Additional species may be introduced in later years.
Ecosystem function	Planning emphasis is to add components of ecosystem structure (such as nutrients or species) to site.	Planning emphasis is to repair ecosystem function.
Maintenance requirements	Moderate	Little or none.

Recommended approach

The approach should be to begin by identifying goals and constraints to those goals. Then we need to assess the status of essential ecological processes and develop alternative strategies to repair each of the identified problems. After assessing the risks of each alternative and their likelihood for success, the complete repair plan is developed (see Chapter 8). Since the potential combinations of unique objectives, approaches, limitations, and wildland types are staggering, step-by-step recommendations for wildland repair are only appropriate for very specific circumstances. A goal of this book is to present a conceptual framework that allows practitioners to develop effective wildland repair programs for any unique combination of circumstances (Figure 1.5). This is most easily accomplished in the wildland context with strategies that (1) are process oriented; (2) seek to initiate autogenic repair; and (3) consider and initiate positive landscape interactions.

PROCESS-ORIENTED STRATEGIES

The recovery and maintenance of processes, rather than species, is the key to ecosystem resilience (Breedlow *et al.*, 1988) and repair (Whisenant, 1995; Whisenant & Tongway, 1995; Bradshaw, 1996). However, wildland repair programs usually emphasize replacing species or nutrients (structure), rather than repairing damaged processes (hydrology, energy capture, nutrient cycling). This book develops a process-oriented approach with an emphasis on managing resource flows and their regulatory mechanisms. This approach begins by assessing the functionality of important primary processes, primarily hydrologic and nutrient cycling (Chapter 2).

Most healthy ecosystems use organic materials to exert and maintain a form of biotic control over nutrient and water flows (Chapin *et al.*, 1997). Degraded ecosystems, with damaged biotic components, have diminished control over these essential hydrologic and nutrient cycling processes. Repairing hydrologic functioning and the mechanisms that regulate resource movement are necessary first considerations during the design of wildland repair strategies. Severely damaged ecosystems have physical limitations to recovery (e.g., steps 3 and 4 in Table 1.1) that are addressed by reducing erosion, protecting the soil surface, increasing infiltration, increasing the water- and nutrient-holding